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CODING SYSTEMS AND THE COMPREHENSION OF INSTRUCTIONAL MATERIALS

Final Technical Report of Research

Under Contract No. F44620-73-C-0056

Sponsored by Advanced Research Projects Agency

ARPA Order No. 2448

For the Period

1 May 1973 through 31 August 1976

ARPA Order: 2448
Program Code: 3D20
Contractor: University of Oregon
Effective Date of Contract: 1 May 1973
Contract Expiration Date: 31 August 1976
Amount of Contract Dollars: $332,417

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0.0 TECHNICAL REPORT SUMMARY

0.1 Objectives

experimentation

The ~~Our~~ goal in this project was to try to bridge the gap between cognitive psychology and instructional technology. For the most part, contemporary cognitive psychology is built upon experiments that employ extremely simple, arbitrary and meaningless stimulus materials with respondents who spend only a total time that rarely exceeds a few hours. The new area of semantic memory, however, has encouraged us ~~to experiment~~ with stimulus materials that are more complex, meaningful and highly organized. Questions can be asked

Document focuses ~~We focus~~ upon the interaction between what an individual already knows and new inputs. On the one hand ~~we can ask questions~~ about how the content and organization of the old information affects the individual's ability to deal with the new input. Under what conditions is the [illegible] input altered or distorted so as to better fit with the old? ~~We also can ask questions~~ about how the new inputs affect the stored information. Under what conditions does the input lead to a change or modification of previous knowledge? Such questions are all related to the broader question of the different ways individuals encode new information and how such encoding affects later utilization of that information.

Questions can also be asked

0.2 The Framework

The framework within which the project was carried out viewed the learner as a limited capacity processor of information. The central processor has only a limited amount of resources to allocate among competing inputs. The capacity of the processor is in terms of "chunks" or meaning units. To make instruction more efficient, in this framework, is to find ways for the learner to overcome the limitations of the limited capacity of his central processor. This can be done by so practicing various skills that they become automated and so can bypass the central processor. Related to such automation is the formation of higher order units or chunks within a given area of speciality. Since each chunk is handled as a single unit, chunks that contain or point to several items of information greatly increase the information processing abilities of the central processor. Still another, but also related, way of improving efficiency is to more quickly anticipate which aspects of the input can be rejected or ignored. If items can be rejected low down on the chain, this saves precious processing capacity for more important items.

Another aspect of the framework is the consideration of levels of processing. The lowest level we consider is the output of sensory analysis which yields various sorts of units--features, chunks, patterns--based upon the physical properties of the input. These features and physical patterns, in turn, serve as the input to a look-up system that retrieves lexical and syntactical information. The results of the look-up provide the materials for constructing surface structures such as words, phrases, and the like. These surface features, in turn, become the basis for constructing underlying propositions from the input--the propositions, in many contemporary systems, being the basic units for both memory search and storage. Sets of propositions, in turn, make up higher order structures variously called schemata, frames, scripts, and plots. It is these

higher order structures that provide the basis for comprehension of inputs. The input tends to result in one such structure being accessed as the likely candidate. The structure contains nodes some of which are filled and others which are waiting to be filled. Once such a structure has been activated it serves to guide further search of the input to find items to fill its slots or variable positions. Such a structure also supplies the basis for inferring other information about the input and "filling in" missing portions, correcting errors due to noise, etc.

Considering the processing as taking place from sensory analysis up through propositions and then to schemata, is only part of the story. This is called data-driven or bottom-up processing. Viewing the processing as going in the other direction, from higher order structures down through to features of the physical input, would be called conceptual-driven or top-down processing. Any realistic model of human comprehension must assume that both top-down and bottom-up processing occur simultaneously. At various times one or the other type may predominate, but processing is never purely one or the other.

Many questions are raised within this framework. Top-down processing can be very efficient, especially when there is redundancy in the input and the learner is appropriately exploiting this redundancy. The expert is one who can bring to bear an appropriate higher order structure which enables him to quickly pinpoint those aspects of the input that are worth further processing. At times, however, the system can be badly mistaken and wrongly interpret the input in terms of a higher order structure because it did not do enough bottom-up processing to realize its initial preconceptions were wrong. Some of our work is aimed at helping to understand when top-down processing is helpful and when it leads to imposing preconceived ideas upon the input.

0.3 The Plan

The project consists of overlapping subprograms which aim to supply information relative to one or more levels of processing in the framework. Reicher and his associates took special responsibility for the lowest level in the chain--that of initial encoding and units. Wickelgren and his associates dealt with middle levels, especially categorization and propositional representation. Hyman and his associates concentrated upon the higher order structures.

0.4 Coding Units

Many experiments were successfully carried out at this level. We confirmed previous work that experts in a given area are superior because they possess a large number of schemata that can be called into play and guide top-down processing in a given situation. That such expertise is confined to the situations that commonly occur in the special area was demonstrated by showing that experts and non-experts are reduced to a common footing when unusual and unlikely arrangements of the materials have to be dealt with.

Two major studies on the word superiority effect were conducted. One demonstrated that subjects are flexible in the coding systems they employ to form a "chunk" out of the word. They generally tend to rely on articulatory codes; but they can switch to visual chunking when many homophones are in the list. Another study seemed to indicate that even when the task is to respond

in terms of a component of the chunk (a letter instead of the word), the subject encodes the higher order unit and then "unpacks" it to get at the lower order unit contained in it. Such a finding accords with earlier theorizing, such as that of Konorski on gnostic units. The features that contribute to the achievement of a highly organized perceptual unit are not ordinarily available to the conscious processor.

0.5 Categorization

The codes or units that are outputs of the sensory analysis of the stimulus materials serve as the basis for contacting lexical memory through a match process. Hyman and Frost studied some models of how this match might occur in a pattern-recognition task. They found evidence that at least three different modes of identifying and classifying patterns are employed by subjects depending upon such things as stage of mastery and type of pattern. Corbett also studied such models within the framework of a mini-semantic system. He found that the identification and classification of patterns by perceptual means agreed with the pattern recognition results, but classification in terms of the names standing for these same patterns did not. Here we have two different sorts of look-up processes for the same referents depending upon the format (visual or verbal) in which they are presented.

0.6 Propositions

Wickelgren developed a theoretical basis for distinguishing among three basic propositional representations--predicate grammar, relational grammar, and operational grammar. Dosher used the speed-accuracy paradigm, which was developed under this project, to investigate implications of retrieval from propositional memory. She found that the subject, verb, and object components of a proposition acted as a single unit in memory. This is somewhat compatible with a special form of the relational grammar, but it is inconsistent with the sort of predicate grammar advocated by Anderson and Bower.

0.7 Schemata

Hyman developed an impression-formation paradigm to study the interaction of top-down with bottom-up processing. In a series of studies he found evidence for both types of processing. When a subject is processing new information that is consistent with his expectancies, he processes it in a highly generic way. He can later correctly call the general class or category of input that he was exposed to, but not the particular item. This contradicts at least some of the implications of the current emphasis on "levels of processing" frameworks. Information that is compatible with what one already knows is supposedly processed to a deep level and remembered better. This is only a half truth according to Hyman's findings. Only very general aspects of such input are remembered. If discrimination from similar inputs is desired, such processing is ineffective.

When a subject encounters new information that is inconsistent with his expectancies but which he nevertheless tries to integrate with existing knowledge, he encodes the new information in a highly particularistic or bottom-up

manner. His recall for such input is not as good as for more generic encoded material, but his recognition memory is more accurate in the sense he does not confuse such inputs with similar items.

Other work on higher order structures was done by Hyman in terms of loading constructed data bases into subjects' memories. Such a procedure is feasible, but runs into difficulties because under some conditions subjects employ a mixed strategy to encode the material. Both O'Oell and Farley tested various models of higher order representations coming out of the work on linear orderings. O'Oell found evidence against a propositional encoding and Farley found the Frame Instantiation model superior to both the Storage and Inference and the Network Construction models. In the Frame Instantiation model, the person comprehends input by accessing a higher order structure that has slots for variables to be inserted. Comprehension is achieved by finding instances in the input that fit into the various slots of the frame. The frame then serves as the basis for making a variety of inferences about information that were only implicit in the input.

1.0 INTRODUCTION

As the title indicates, this project was guided by a concern for instruction. We are experimental psychologists who specialize in cognitive psychology. Cognitive psychology attempts to study and understand how humans acquire and use knowledge in coping with their environments and problems. It seems obvious that the experiments and theories on perception, acquisition and retention of information, attention, decision making, concept formation, skill learning, and thinking should be relevant to problems of instruction. But when we look closely at the results of research and theorizing in cognitive psychology, we do not see immediately how these apply to the questions raised by instructional technology.

We can probably generate a number of plausible reasons why it is difficult to find direct relevance of cognitive psychology to instructional concerns. For one thing, many of the questions and objectives of cognitive psychology were not initiated by a concern for instruction. But just as significant is the huge gap that exists between the materials and tasks employed in psychological research and the materials and tasks that typify an instructional program. In his concern for strict control, the experimental psychologist typically employs stimulus materials such as simple patterns or unrelated lists of words that are devoid of meaning and organization. Even when the materials do possess meaning--such as sentences or pictures--the contents have no obvious relevance to the past or future concerns of the subject who is to respond to it. In addition, the total amount of material to be mastered or dealt with in an experiment is many orders of magnitude less than the amount that has to be mastered in even the most modest of instructional programs. This last point is also related to the amount of time that subjects are observed interacting with the materials in an experiment. Typically, a subject is observed in one or two experimental sessions lasting approximately one hour. Compare this with the number of hours a student devotes in a course of instruction. For a typical college course, for example, 100 hours would not be a lot.

We could add other reasons. The motivation, task requirements, mode of testing, and many other attributes suggest other differences. None of these reasons, however, prove that cognitive psychology is irrelevant to instructional technology. Rather, they suggest why it is currently difficult to know in what ways, if any, it is relevant. What seems to be needed is a way to bridge the gap between a body of knowledge and theory based on artificial and simple materials and tasks and a set of concerns about how meaningful and large bodies of knowledge and skills are mastered and utilized. This project is one attempt to bridge that gap.

The title "Coding Systems and the Comprehension of Instructional Materials" suggests, in part, our general approach to the task. The phrase "coding systems" is ambiguous. It refers to certain procedures that subjects perform on information as well as the result of those procedures. Cognitive psychologists take it as axiomatic that people do not respond to the stimulus materials directly; instead, they respond to the materials as they "interpret" them. In other words, they respond to a <u>representation</u> of the situation or problem that confronts them. We can predict subsequent behavior on the basis of the stimulus only if there is a one-to-one correspondence between the stimulus and the representation. But

such a correspondence is probably never realized. The subject cannot register all the properties of the stimulus. Of those that he can detect, he is quite selective about which ones will contribute to his representation of it. The representation, in addition, contains information not directly available in the stimulus. This information comes from the preceding occurrences of other stimuli as well as the current context of other occurrences. The representation is further influenced by the subject's past experiences, his values, his attitudes, and other factors.

So a central concern of this project is with how subjects encode stimulus materials. One obvious determinant of the encoding is the task given to the subject. Assume that the stimulus is the printed proverb, "A rolling stone gathers no moss". Consider three possible tasks: (1) to determine if a given letter, say "u", appeared in the display; (2) to repeat verbatim, after a short interval, the exact words in the display; (3) to supply an equivalent paraphrase using different words. We have good reason, on the basis of recent experiments, to believe that subjects encode the display quite differently for each of these tasks. What they retain is also markedly different. Many measures of performance that typify laboratory research would show superior results for the first two tasks over the third. This would be especially so for any task that demands literal reproduction.

Yet, it is the third task that comes closer in spirit to capturing the goals of most instructional programs. The first two tasks, so typical of laboratory experiments, demand no comprehension and, in fact, encourage a type of coding and rehearsal that interferes with comprehension. The third task, which is more typical of some recent work in semantic memory, actually interferes with the accomplishment of the first two tasks but leads to greater long term retention of the underlying meaning. Our use of the word "comprehension" in our title emphasizes that we will be focussing more on tasks of the third kind rather than the more traditional tasks that emphasize literal or close correspondence between the physical properties of the stimulus materials and the output from the subject.

Finally, the use of the term "instructional materials" indicates that we will be oriented towards stimulus materials that are highly organized and meaningful to the subjects. This does not mean that we will use actual instructional materials. Such materials would be too drastic a change from our normal laboratory fare of nonsense words and random designs. But we can move several steps towards the ideal of dealing experimentally with instructional materials by employing stimulus materials that approximate to many aspects of such materials while, at the same time, retaining some control on the contents and structures.

1.1 <u>Objectives</u>

One objective, as indicated in the preceding introduction, is to conduct some basic research in cognitive psychology that will be more obviously relevant to instructional concerns. An obvious way to do this is to employ stimulus materials that are more like instructional materials in being meaningful, highly organized, and relatively complex. Along with this, we can have subjects perform tasks that emphasize comprehension of the materials rather than ones that emphasize literal reproduction. We can further constrain our goal by looking at some overlapping issues in cognitive psychology and instructional technology.

The goal of an instructional program is to change the student in some more or less permanent way. The program succeeds to the extent that the student emerges with new knowledge, skills or attitudes. From the viewpoint of cognitive psychology, this implies a change in long term memory. Here we deal with the acquisition of knowledge and skills. It is not enough to merely add such information to memory. The real challenge is to add it to memory in such a way that it will be accessible when it is needed in subsequent situations. This is the problem of retrieval, and much of contemporary work on semantic memory recognizes the retrieval problem as the most important issue relevant to long term memory. Quite frequently, what looks like a problem of simple forgetting is not really a situation in which information has been lost from memory. Instead, the information is still there but not readily retrievable. Much contemporary work suggests that subsequent retrieval of stored information depends heavily upon the context and manner in which the information was originally encoded. One broad objective, then, is to study how the context, task, and initial encoding of information affects its subsequent accessibility.

The preceding paragraph deals with just one facet of the general issue of the interaction of past experience with current inputs. The learner brings with him a lot of stored information into the learning situation. We can look upon this stored information--its content and organization--either as the dependent variable or the independent variable. As the independent variable, we can ask how does the already stored information affect the way a person deals with new inputs. At one extreme, the new input could be completely redundant with what the subject already has in store. Presumably this would lead the subject to recognize the material as completely familiar and lead him to devote little if any attention to it. At the other extreme, the new input might have no overlap with any stored information. Under these conditions it is unlikely, according to current theories, that the learner could make sense of the material or process it in any way. The most typical case is where there is a partial match or correspondence between the input and relevant stored material. We now have two possibilities, both of which actually occur in the laboratory and in real life. One possibility is that because of the partial match, the subject will treat the entire input as a complete match. Such complete assimilation results in overlooking or ignoring discrepancies or novelties in the input. The other possibility is that the discrepancies in the input will be highlighted and emphasized just because they do not match what is stored in memory. Such contrast results in attention and resources being devoted to the mismatched portion. An important objective of our project is to try to understand when such discrepancies in input are suppressed and assimilated and when they are emphasized and attended to.

We also focus upon the stored information as the dependent variable. We want to know how it is modified as a result of encounters with new inputs. Here we have to make the distinction that has recently been made between semantic and episodic memory. Semantic memory refers to general knowledge about the world that is not tied down to specific occurrences and events in time and space. The subjective lexicon, that contains information about word meanings and usages, for example, would be part of such a memory. Episodic memory is the record of specific events or episodes that actually occurred. The two sorts of memories are intimately related and there is some debate as to how the distinction should be made and if it should be made at all. If the teacher tells Johnny that Whales

are Mammals, this information could affect both his semantic and episodic memory. If Johnny had previously believed that whales are fish and subsequently treats whales as mammals this represents a change in his semantic memory. But his memory for the event that the teacher told him such a fact on Wednesday, June 1, 1976 is part of his episodic memory for that occurrence. Notice that the episodic memory was enabled by Johnny's previous semantic memory about whales and mammals.

Instruction, for the most part, concerns semantic memory. It is aimed at changing general knowledge and skills in such a way that the student can function more effectively in a variety of future situations. The tennis instructor presumably is not concerned with the student's ability to remember on which day he taught him the backhand. But he is interested in the student being able to employ the backhand when it is appropriate during a tennis match. Instruction that leaves semantic memory unchanged is by definition a failure. We can guess that information that is sufficiently similar to what is already stored in semantic memory will produce no change. We can also surmise that if the new input makes no contact at all with what the learner already knows, it cannot create any modification in semantic memory.

The most interesting cases, then, are those in which there is partial overlap or matching between new inputs and what is already known by the learner. One interest is under what conditions the discrepant or novel part of the input can produce changes in existing memory structures. And another interest is in the form of these modifications--deletions, replacements or substitutions, additions, new combinations or differentiations, etc.

A general objective, then, is to investigate the reciprocal effects of new inputs and old memories. Under what conditions and in what ways is the new input assimilated (altered to fit into) to the existing content and structure of the previous memories? Under what conditions and in what ways does the new material force the previous memories to change (accommodation)? Beyond this we want to ask: how does the initial encoding of the new material and the way it is added to long term memory affect its subsequent accessibility in future situations? And, given that information is already stored in memory, what sorts of retrieval strategies are optimal for finding it in new situations?

Such objectives, in turn, imply that we can adequately specify both the structures in memory and the ways in which they are modified. It also implies that we can specify the stimulus materials in such a way that we can evaluate just what the subject has extracted from them and how he has encoded it. Another goal, then, must be to develop reasonable ways to specify the contents and structures of memories and of stimulus materials.

1.2 The Framework

The metatheoretical framework that guides this project is a loose amalgam of notions from cognitive psychology, semantic memory, and artificial intelligence. The basic notion is that the individual, in coping with the environment, has a limited capacity to allocate among competing informational inputs. Some disagreements exist about the nature and type of limitations on processing capacity, but the best guess is that the limits apply to a central processor

that deals with those aspects of inputs that are of most concern to the individual at a given moment. The information being handled by this central processor is sometimes treated as equivalent to what is in "working" or immediate memory, to what is being "attended", or even to "consciousness". This central processor can hold in store only a small number of separate elements or "chunks"--usually around seven at most--and it deals with them sequentially. Much processing of information occurs outside the central processor. Such processing can occur in parallel and involves functions that are "automated"--i.e., require no attention or conscious resources. Some of the outcomes of such automated processing bypass the central processor completely. These correspond to acts such as walking, driving over very familiar routes, and other habitual activities that can be carried out unconsciously. Other outputs of such automatic processing are inputs to the conscious processor. Some entire sequences of automated activities (controlled by motor programs) can be initiated by conscious action, but then left to subconscious control. For example, it may require conscious attention to decide to throw a fast ball on the next pitch. Once this decision has been made, however, the remaining aspects of the action might be carried out without involvement of the central processor which, say, is entirely taken up with monitoring the runner on first base.

The limited capacity and sequential mode of operation of the central processor represents a "bottleneck" that can impede efficient information processing, especially in unfamiliar situations. It is this informational bottleneck that is responsible for many breakdowns in carrying out skilled activities under stress or informational overload. Yet, highly practiced and skilled individuals seem to have little trouble handling complex informational transactions under conditions that would completely stymie a nonexpert. If a chess grandmaster is allowed only five seconds to look at a position from the middle of a chess game, he usually can replace all the pieces (typically about 24 in number) back in their original places. An ordinary chess player, under the same circumstances, manages about six correct replacements. What accounts for this apparent ability of experts to bypass the central processing bottleneck?

How to overcome this "bottleneck" is one of the interests of the current project. But some tentative answers can be given within our framework. In a sense, the capacity of the expert is much greater than that of the nonexpert. Twenty-four chess pieces in immediate memory certainly represents a greater capacity than four chess pieces. But in another sense, cognitive psychologists do not attribute such superiority to a difference in capacity. This is because the psychologist measures the capacity of the central processor not in terms of some objective measure of information, but rather in terms of the number of meaningful units involved. Sometimes these meaningful units are called "chunks". If the subject is given the task to cope with a string of unrelated letters in immediate memory, he will be able to handle approximately six or seven. If he is given a string of unrelated words, each of five letters in length, he will be able to handle six or seven of them. In terms of number of letters, the latter situation represents a five-fold increment in capacity. In terms of meaningful units or "chunks", however, both situations reveal the same capacity. In these terms, then, the grandmaster's superiority lies not so much in a greater capacity, but rather in being able to deal with the chess pieces in terms of higher order groupings or chunks.

So one way to get around the capacity limitation is to organize the material into higher order units or chunks. Such organization presupposes prior experience and practice at isolating and forming such higher order units. We know that the grandmaster's organizational ability depends upon his familiarity with chess games. If the same pieces are placed on the board at random, he now can no longer take advantage of meaningful patterns that occur in chess games. Under such circumstances his ability to correctly replace pieces drops to around six, the same as that of the ordinary chess player.

Another way to get around the capacity limitation is to automate as much of the processing and motor control as possible. The more information handling that can be automated and handled outside the central processor, the more capacity is left for the processor to handle other matters. Automation and the use of higher order codes are interrelated. The chunks employed by the expert can be viewed as the outputs of perceptual grouping operations that have been automated. Still another way to deal with the limited capacity of the central processor is to become more efficient in selecting what inputs reach the processor. Experts not only excel in employing higher order codes, but they also are good at not devoting precious resources to irrelevant inputs. The grandmaster, it has been shown, rejects many moves from further consideration after considering them only for one level in depth. The ordinary chess player wastes precious resources by considering the same moves for two or three levels in depth before deciding to abandon them.

Within our framework we can depict the learner as going through a number of levels of processing. At one extreme, processing starts with sensory analysis of the physical patterns in the instructional materials. Such sensory analysis yields such attributes as features, dimensions, and patterns which characterize the physical properties of the input. It corresponds to a parsing of the physical input into units, chunks, etc. The output of this parsing retrieves through matching syntactical and semantic aspects of the input that correspond to various surface structure features such as morphemes, words, phrases, etc. The output from this surface structure processing, in turn, serves as the input to representations of the material in terms of underlying propositions. These propositions, in turn, are integrated into higher order structures such as frames, schemata, story plots, etc.

The preceding paragraph describes a more or less classical picture of information flow from sensory input through to ultimate comprehension or meaning. It is obviously wrong as a complete picture of the process, but does represent one part of the picture. Such a view of the processing, going from sensory analysis up to higher order meaning structures, is called a data-driven or bottom-up system. It represents a caricature of what might take place when a person was confronted with a novel input for which he had no prior context or expectations.

An alternative view of the processing reverses the direction of control and conceives of the system as starting off with hypotheses and higher order structures of what to expect and then working down from these expectations to tests for features and patterns in the physical properties of the input that should be found if the initial expectancies are correct. Such a processing mode is called a conceptually-driven system or top-down processing system.

A conceptually-driven system is much more active than the data-driven system; it does not passively accept the input as presented and then work up an interpretation; rather, it makes guesses and tentative interpretations and then seeks out key features in the input that will verify these initial guesses.

The human, as well as the sophisticated artificial processor, employs both modes of processing simultaneously. Psychologists tend to view the bottom-up mode as occurring automatically and not necessarily involving conscious attention (although the outputs from such automatic processing can serve as inputs to the central processor). They tend to view the top-down mode as involving the conscious processor to a greater degree.

At any point in dealing with inputs, the individual could be viewed as emphasizing one mode more than the other. For example, early in the process of reading material for which the person has no prior expectancies, he would most likely be operating more in a bottom-up mode. But very quickly the information would generate a limited set of expectancies about the sort of subject matter and topic that was being treated. These expectancies would then lead to active checks on subsequent material in the input. As more and more of these checks confirm the initial expectancies, the processing would swing more and more to a top-down mode. But, if at some later point, some unexpected information was encountered, the reader would be forced to shift into a bottom-up mode until new possibilities had been generated.

Many years ago Edna Heidbreder discussed two types of strategies in concept learning tasks. In what she called spectator behavior, the subject was passive and allowed the concept to emerge without any attempt to analyze or anticipate it. In what she called participant behavior the subject actively searches for information to test hypotheses he has generated. Spectator behavior corresponds to bottom-up analysis and participant behavior corresponds to top-down analysis. Both forms of behavior occur within a given subject as he goes through the process of learning a concept.

Top-down processing can be quite efficient. Not all of the material has to be fully analyzed and processed. Only the most relevant aspects of the information need be extracted from the input. But such efficiency can occur only when there are redundancies to be exploited and the subject has a clear idea as to what sorts of information are relevant. Top-down processing can also lead to gross distortions and false beliefs about what the material contains. Preconceptions can bias how the material is encoded and interpreted and can run roughshod over parts of the input that are contradictory or inconsistent with initial hypotheses.

Another of our objectives is to try to determine under what conditions top-down processing is efficient and adaptive and under what circumstances it leads to distortions and false information. Both outcomes occur. But we do not know how to predict which it will be in advance.

1.3 The Plan

Our plan of operation, in part, is implicit in the preceding sections. The main idea was to apply the concepts, theories, and methods of cognitive

psychology, especially those arising from our previous ARPA contract on "Coding Systems in Perception and Cognition", to experiments involving meaningful stimulus materials and much more time per subject. Many of the ideas on levels of processing, coding systems, and capacity emerged from this research. Also, many useful methods such as the chronometric approach, probes in divided attention tasks, and pattern recognition tests that were successful in the earlier project seemed promising for the present venture.

At the same time we knew that we would also have to develop new paradigms and new methods of data analysis to handle the greater complexity of our stimulus materials and response outputs. This would involve some theoretical development as well, especially in ways to represent the underlying propositional structures of stimulus materials and subjects' memories.

We planned to use the first year as a "tooling up" period. During this period we would develop and test out various paradigms. We conceived of the second year as both a time for collecting data and also a time for devising an adequate framework within which to integrate and direct the research efforts. And we envisioned the final year as a concentrated attempt to carry out a successful series of experiments within the framework.

In retrospect, these plans were implemented more or less as we anticipated.

1.4 The Subprograms

The project was conceived as a number of overlapping subprograms--each contributing to one or more aspects of the total framework. Both Reicher and Schaeffer, in different ways, were to focus on the initial encoding stages--the parsing of inputs into units and chunks for later processing. Schaeffer was interested in developing a laboratory analog to different stages that might occur as one went through different degrees of mastery of a coding system. Reicher was interested in symbolic codes that stand for chunks of information. He wanted to investigate in what ways such codes "carry" the information they represent. In addition he was interested in "sophisticated encoding". He wanted to investigate in what ways the initial encoding of experts differed from that of novices.

The outputs of such initial encodings serve as a basis for matching processes to identify or categorize parts of the input. We can refer to this matching process as categorization. Both Hyman and Corbett, one of Wickelgren's students, hoped to make contributions to this problem. Corbett, in particular, wanted to combine ideas from work in pattern recognition with that in semantic memory on how individuals learn to categorize hierarchically ordered materials.

Once units have been identified or categorized they presumably can be represented within a propositional framework. Most contemporary systems of semantic memory such as HAM, LNR and Kintsch's system, assume that propositions are the basic elements of long term memory. Propositions contain at least two elements, typically a concept and something predicated of that concept. A nominal proposition, for example, consists of a concept and some property assigned or attributed to that concept. Other propositions consist of two or more concepts and a relation holding between them. Although there is general

agreement that knowledge is stored in memory in the form of propositions, there is disagreement about such things as what sort of a propositional representation to employ (e.g. predicate grammar, relational grammar, or operational grammar) and whether all information in memory need be propositional (or if some could be in non-propositional, analog form). Wickelgren planned to contribute some theoretical perspective on this problem and his student, Dosher, planned to do her master's thesis on an experimental examination of different formats for representing propositional information.

The most elusive, yet the most compelling, level of representation is that of higher order structures made up of propositions. These have been called such things as "frames", "schemata", "story plots", and "scripts". Although each of these concepts has been developed in somewhat different contexts, they all refer to higher order meaning structures which both guide the over-all processing and serve as the basis for the ultimate comprehension of the input. Hyman and his students planned to concentrate their major effort at this level. Even though it promised to be the most difficult to experiment with, and although no precedents existed for how to characterize or investigate such structures (at least when we initially conceived this program), we felt it was most important to attempt to investigate such structures. To fully understand the comprehension of instructional materials we need to have a handle both on the sorts of units that emerge from the initial encoding of the stimulus input and the sorts of structures into which these initial encodings are eventually integrated in the attempt to comprehend the input.

2.0 CODES AND UNITS

2.1 The Representation Problem

A key problem in trying to do research on semantic material is the representation problem. This problem has both a pragmatic and a theoretical aspect. The pragmatic aspect is the need to describe or represent the content and structure of our stimulus materials. Unless we devise adequate ways to describe and quantify the stimulus materials, we will have no way for aseessing to what extent, if any, the subjects' outputs are determined by the presented material.

And, in those cases in which we want to fully assess what the subject has extracted or "comprehended", we also have the task of representing or describing his output.

The theoretical question comes from the desire to know how the subject represents or encodes the stimulus information. What is it, in fact, that he is reacting to? What has he grasped of the material he has been given? This question is especially urgent in the present project because, unlike the simple and nonsense stimulus materials, semantic material can be encoded and organized by individuals in almost limitless ways.

Ideally, both the pragmatic and theoretical representation problem can be solved with the same system. But the two representations need not be the same. What is needed is a descriptive system for the stimulus that is sufficient to capture most, if not all, of the possible variability that an individual subject can pick up.

One aspect of the representation problem deals with the different sorts of units that might be used to process the information in a stimulus. For example, in written instructional material, one could deal with individual letters, morphemes, individual words, phrases and surface structure units, propositions, sentences, "themes", paragraphs, etc.

As the preceding example illustrates, many types of units often form a hierarchy. Letters are included in words, words are included in sentences, sentences are included in paragraphs, etc. Which of these types of units have psychological consequences? If they all do, how do the components and the wholes relate to each other?

2.2 The Word Superiority Effect

Two different research projects on our contract have been devoted to what is called the "word superiority effect" or the "Reicher effect". The effect is often called by the latter name because it was Reicher, currently one of our co-investigators, who both developed the paradigm and demonstrated the phenomenon in his dissertation which was published in 1969. Reicher and Hawkins, a visitor from the University of South Florida, have been actively pursuing a new set of experiments based on this paradigm. And Polf, under Hyman's direction, did her doctoral dissertation on another aspect of this phenomenon.

The phenomenon was first demonstrated by Reicher in the following situation. The subject is shown a stimulus for a very brief period of time (typically, 30 to 50 milliseconds). The stimulus consists of either a single letter, a string of unrelated letters, or a word. Following the stimulus presentation, the subject is presented with a test consisting of a pair of letters, one of which was in the preceding stimulus. The subject's task is simply to identify the letter that was in the target stimulus. Reicher found that the subject was more accurate when the letter to be recognized had been part of a word than when it had been presented in isolation or as part of a meaningless set of letters. Other experiments have replicated this finding several times.

For our purposes the phenomenon has interest because of what it might tell us about how higher order units carry information about their components and vice versa. The phenomenon and its accompanying paradigm might be another way to investigate the elusive but obviously very important concept of the "chunk". In the Reicher paradigm, it seems fairly well established that the effect depends in some way on the word being a unitary object. For example, the effect disappears or reverses when the subject has to identify which letter occurred in a meaningless and unpronounceable string of letters.

It also seems that the effect can be affected by whether the subject is focussing upon the individual letters in the stimulus or upon the set of letters as a coherent unit. In the experiment as typically run the subjects tend to encode the entire letter string as a unitary "chunk" rather than as a set of individual letters (or features). This is relatively easy to do when the letter string forms a familiar word or is pronounceable. But it is difficult or impossible to do when the letter string is a meaningless jumble.

Johnston and McClelland, for example, did the experiment under two conditions. In the letter condition, the subject was deliberately instructed to treat the word as a set of individual letters. To further help him in this task, he was told in advance which letter in the word would be tested. In the word condition, the subject was told to focus on the word as a whole rather than the individual letters. In this latter condition he was not told which letter in the word would be the test letter. Despite this disadvantage, the word condition showed the superior accuracy. That is, when the stimulus was JOIN, and the subject was told that the first letter was to be tested, he was still less accurate in recognizing whether the first letter had been "J" or "C" than was a subject who had been shown JOIN and told to concentrate on the entire word.

These same experimenters got the opposite result when they gave subjects a letter string such as JPRD and then tested them to see if they could remember if "J" or "C" had been in the stimulus. Subjects in the letter condition were now superior to those subjects who were trying to treat the letter string as a unit.

What sort of a unit or "chunk" is the word in this condition? Is it a visual sort of chunk or code? That is, does the word form a familiar perceptual pattern of visual features, letter combinations, or configuration of some sort? Or is the course of the unit some sort of articulatory or auditory code. Maybe the subject recodes the perceived string of letters into some sort of pronounceable sound? Or is there a psychological unit that corresponds to meaningful words as such?

Reicher and Hawkins have devised a variety of experiments to get at this question. We do know, for example, that pronounceability, as such, is sufficient to generate the Reicher effect. But Reicher and Hawkins believe that words still have a "chunk" or coding effect over and above simple pronounceability. Indeed, there may be a multiplicity of codes or chunking systems any or all of which may come into play in given circumstances. It makes sense to suppose that subjects will employ whatever strategies they can to simplify and unitize the material before them.

Hawkins, Reicher, Rogers and Peterson (1976) have published the results of these experiments. They conclude that, in their situation, some non-phonetic coding mechanism must be operative at least some of the time. The evidence further suggests that the use of one coding mechanism rather than another is strategy dependent.

Reicher et al. demonstrate that a phonetic code does seem implicated in their task. When the list of words contained a few homophones, the subjects could not differentiate between the homophones. This is consistent with the hypothesis that they encoded the word by its sound. But when Reicher et al. made sure that the subject knew he was dealing with lists that contained homophones (by both informing him and increasing the proportion of such words), the difficulty with homophone confusions disappeared. This latter finding is consistent with the hypothesis that the subjects, when the occasion demands, can employ codes other than acoustic.

Davidson is following up this work to find out if other codes used in the high proportion homophone condition are visual or semantic. In his first experiment, he could not duplicate the homophone effect. He is now trying to replicate that effect by using the same conditions as Reicher et al. The series of experiments on the type of coding and how much freedom subjects have to choose a code will be the basis for Davidson's master's thesis.

Polf was concerned with another aspect of the Reicher effect. Granted that the subject chunks the letter string into a unit, how does this unit help him to recognize an individual letter that is a component of the chunk? And what is the mechanism by which he does so?

One possibility that Polf entertained could suggest that the effect was essentially an artifact. Up to now, the Reicher effect has been demonstrated under conditions in which times to respond were not recorded. But some investigators, including Reicher, have informally observed that subjects take more time to respond when the stimulus consisted of a word than when it was an individual letter. Perhaps, in processing a word rather than a letter, the subject simply rehearses the individual letters longer than when he gets a single letter. His subsequent improvement in accuracy, then, would not be because the letter was embedded in a meaningful unit, but because the processing of the unit resulted in the subject spending more time on the individual letters.

Some indirect evidence about time to process words would argue against the preceding interpretation. But other evidence could be mustered in its defense. What is needed is a technique that simultaneously takes both time and accuracy into account. Fortunately, Wickelgren and former student Reed, partly supported by the current project, have developed a new speed-accuracy paradigm to simultaneously deal with speed and accuracy within the same experiment and analysis (see below). Polf adapted their procedure to dealing with how the chunk facilitates accuracy in identifying individual components.

Incidently, Polf's dissertation is an ideal example of the type of cooperative research we try to encourage on projects such as this. Polf did her dissertation under Hyman's direction. The framework in which her question is posed comes out of the research program being pursued by Hyman. But the paradigm that she employed is one developed and used by another investigator in our project, Reicher. And the methodology (which is another paradigm in its own right) which she applied is one developed by still another investigator in the project, Wickelgren.

In Reicher's original paradigm, the subject is free to respond when he feels ready. No control nor measure of response time is employed. In Polf's variation, the subject is trained to respond as fast as possible when he hears a tone. As in the Reicher paradigm, the subject is shown a target stimulus which might be a single letter, a string of unrelated letters, or a four-letter word. A mask follows the target, then a test pair of letters comes on. The subject has to respond, by pressing one of two keys, to indicate which of the letters was in the target. On some trials, the subject does not know which, the tone to respond may occur as soon as 50 milliseconds after the onset of the test pair, or it may occur as much as 600 milliseconds later. Polf used eight different lags over this range. Subjectively, the fastest lag occurs too soon to even know what the test letters are, while the longest lag seems to be more

than enough time to do all the mental processing that one feels necessary. The subjects have to be trained to respond as soon as they hear the tone regardless of how ready they feel.

The results of this and a second similar experiment clearly exclude the explanation that the Reicher effect is merely a matter of speed-accuracy trade-off. When the subject takes anywhere from 450 milliseconds or longer to respond, he is clearly more accurate in the word than in the letter condition. What is more, the more time he has beyond 450 milliseconds, the more his accuracy improves in the word condition. This added time does not help accuracy, however, in the letter condition. On the other hand, when the subject is forced to respond in less than a half-second, he is more accurate in the letter condition. At the very shortest lags, in fact, the subject behaves at the chance level when forced to respond in the word condition. The data suggest, however, that the subject is better than chance for such short lags in the condition.

Polf's results clearly exclude some possible explanations of the word superiority effect. But they are still compatible with more than one possibility. Polf has run additional experiments to try and exclude some of these possibilities. At the moment, the preferred but still tentative explanation would go like this.

When the subject receives the test pair of letters he has already fully encoded the target stimulus. In the letter condition, this amounts to simply having encoded the single letter. The exposure duration of the target is such that he cannot always encode this letter with complete accuracy. But if he has successfully encoded it, his task in the test situation is simply to make a direct match of the stored target with the perceived test letter. While this takes some time, it is still a relatively fast operation, one that does not take more than a half-second to complete. Thus, increasing the response time up to half a second will show improvement in the task, but giving the subject any more time will not help. This, of course, describes the output function obtained by Polf.

In the word condition, the subject encodes the word directly as a unitary "chunk". This chunk, in the words of Johnson, acts as an "opaque container". The chunk does not consist directly of the individual letters in the word. But, if called upon to do so, the subject can recover the individual letters by a further retrieval operation. This additional "unpacking" operation, however, takes time. When the subject is forced to respond faster than 450 milliseconds, he does not have time to fully complete his unpacking and tends to make errors. The more time he has, the more accurately he can unpack or decode the word into its constituent letters and check to see which of the test letters is among them.

With sufficient time, the subject should achieve perfect accuracy in this condition (given that he knows how to spell) because once he has the letter string encoded as a familiar word, he can rely upon his previous learning to infer what the component letters must have been. The task in this latter condition is completely process-limited (to employ the terminology of Norman and Bobrow).

But the accuracy in the letter condition will depend, ultimately, upon how much time was given to perceive the initial target. Even with unlimited time,

the subject cannot improve upon his accuracy if he did not correctly register the letter in the first place. In this latter case, ultimate performance is data-limited.

The importance of understanding the dynamics of what goes of this paradigm is not because words as such are important units. Rather, we feel that what goes on between words and their components can tell us much about the interaction of higher order units and their constituents in general. And this, in turn, we believe will turn out to be one of the crucial issues in understanding what goes on during the mastery of knowledge.

2.3 Experiments in "Sophisticated Encoding"

Reicher and his colleagues have studied skilled encoding. They have tried a variety of converging approaches. In some cases they obtained highly skilled and less highly skilled individuals in the same task. One such task was sight-reading in music. They found, in agreement with the work on chess grandmasters, that the expert in this task was able to work with chunks of larger size than the nonexperts. Simon and others, for example, found that the grandmaster did not excel in the number of "chunks" or units he could handle simultaneously in working memory. By a variety of converging operations it can be shown that the grandmaster and ordinary masters have the same memory span--approximately five to seven chunks. What makes the difference, however, is that the grandmaster works with chunks that contain more information.

We can illustrate this with a simple experiment that de Groot and others have conducted. A subject is shown a pattern of pieces on a chessboard for approximately five seconds. If the pieces represent a position from an actual chess game, the grandmasters can usually reproduce the entire pattern without error (usually around 24 pieces). Ordinary players can get only about six pieces correctly placed in such a task. But if the pattern of pieces is random, then the grandmaster and the ordinary player perform equivalently--each getting approximately six correct. Thus, something about his knowledge and mastery of the game of chess somehow enables the grandmaster to operate with units or chunks that are of the magnitude of four pieces each. A variety of other direct and indirect arguments and experiments seems to indicate that it is in this chunking process that the superiority of the grandmaster lies.

Reicher and his colleagues have shown that it is not just in chess that such superiority of chunking is the key to expertise. The situation seems to be completely parallel with sight-readers when compared with musicians who are not expert sight-readers. Other evidence suggests that this is what underlies skilled performance in quality control and other tasks.

For her honor's thesis, de Lemos, under Reicher's guidance, did a further study comparing good versus poor sight readers at the piano. The technique was simple. Musical chords are displayed briefly and then are followed by two response alternatives that differ in one note. Both alternatives, however, make good musical sense. When the notes are taken from actual music, but music unfamiliar to the respondents, the good sight readers are much superior in this task than are the poor sight readers (the task is to identify which alternative is identical to the original musical phrase). In a followup study, de Lemos compared the good

and poor sight readers on non-musical materials and found no differences in ability. So, the story parallels that of the highly skilled and less highly skilled chess players.

2.4 Representational Requirements for High Speed Visual Scanning

Another approach developed by Reicher is inspired by the frequent reports that, for skilled individuals, the appropriate object they are seeking amidst a collection of homogeneous objects seems to "pop out" from the background. In some of their experiments, for example, the background is composed of letters, while the target is one or more letters in abnormal orientation (mirror-image, upside down). With some practice, the target letter seems to "pop out" almost instantly when presented with the test array. But when the target is a letter or familiar object in normal orientation against a background of letters which are all in abnormal orientation, the task is enormously more difficult. One possibility is that organisms are constructed so as to attend to the unusual or unfamiliar. And when the background is composed of unfamiliar elements, the subject has great difficulty in disregarding it.

This has relevance to extracting meaningful and relevant material from a larger body of information. Data have already been collected in other laboratories that indicate that such a task is relatively easy when the material to be abstracted is unfamiliar, but embedded in a familiar or coherent background. But the task is relatively difficult when the relevant material is familiar and coherent, but embedded in a background that is unfamiliar or incoherent.

One hope is that the pursuit of this issue will give us clues as to how successful individuals are able to attend to just that part of a complex body of information that is relevant to their task.

Reicher, Snyder and Richards (1976) reported on a series of nine experiments that demonstrate that it is much easier to look for an uncommon character embedded among common ones than to look for a common character among uncommon ones. Taken together, the experiments converge on the conclusion that it is the nature of the background items (the ones that the subject is attempting to ignore) rather than the nature of the target items that is more important to performance.

The initial impetus for these experiments arose out of some subjective and counterintuitive experiences by the investigators. But, as we will argue later on, the underlying phenomenon apparently has widespread generality across a variety of naturalistic tasks wherein individuals are trying to extract relevant information from an abundance of input. Reicher's findings seem to have implications, both theoretical and practical, for other research in this project--especially for some of the concerns of Hyman and his coworkers.

Some time ago, Reicher and Snyder were conducting a series of experiments to see if attention to a part of a visual display could be directed by "conceptual" (as opposed to simple physical) information in the stimulus. One task involved searching for a rotated letter in a matrix of upright letters. During some exploratory studies, these investigators completely inverted one of the stimulus matrices to see what looking for an upright letter among rotated ones would be like. They expected that it would be easier than the other way around. They

thought that the one letter in its familiar orientation would be very easy to find against a background of letters that were all in unfamiliar orientations. To their surprise, this task of finding the familiar among the unfamiliar turned out to be quite difficult--much more difficult than the reverse task of finding one unfamiliar form against a background of familiar ones. In the latter case, the subjective impression one gets is of the unfamiliar form standing out against the background--sometimes it literally seems to just pop out. In the reverse situation, the subjective impression is that the unfamiliar forms in the background keep competing for attention, making it difficult for the one familiar target to stand out.

Reicher, Snyder and Richards describe their initial decision to study this phenomenon with the following justification:

> We believe that this is an interesting phenomenon in itself and also that it is theoretically interesting in several respects. It is evidence of directing attention by conceptual information... Further it seems to suggest one or both of two interesting possibilities. One is that people can ignore familiar but not unfamiliar items. The alternative is that unfamiliar items attract attention. Our subjective impressions were that the ability to ignore familiar but not unfamiliar items was the more important factor. What is particularly interesting about being able to ignore only well known characters is the implication that the act of ignoring this task requires well developed memory representations of the characters. The ability to make decisions about well learned information with little conscious involvement seems a requirement for a variety of perceptual skill. For example, highly skilled inspectors of manufactured goods may not consciously know why they rejected particular items unless there is some reason (and extra time) to look back... Chess masters show their ability to make better unconscious decisions in the observation that they consciously consider not more but better moves than lesser players... Reading might also involve unconscious monitoring of routine materials.

The basic experiments involved showing subjects a matrix with nine characters. On target-present trials, eight of the characters were background items and one character was a target item. On target-absent trials, all nine matrix positions were filled by background characters. The types of unusual characters employed were rotated English letters, partial letters and Gibson figures. The common characters were usually upright English letters but on one occasion they were digits. Search was easier through common backgrounds than through unusual backgrounds with all of the character types employed and whether measuring speed or accuracy.

Several alternative explanations might account for these findings. Some of the alternatives would make the findings uninteresting. For example, one possibility is that the subject merely examines each of the items in the matrix, one at a time in a sequential fashion. He identifies each item before moving on to the next until he arrives at an item that matches the target he is seeking. The results, given this alternative, would be explained on the basis that it takes longer to identify an unfamiliar item than it does a familiar one. The

results become of more interest if it can be shown that we are dealing with an automatic, attentional phenomenon. The nine different experiments were designed to eliminate various alternatives and to pin down the most likely explanation.

Taken together, the set of experiments enables the authors to conclude the effect is not due to conscious sorting through of individual characters. From their findings, they draw the following implications:

> In many ways, people seem especially prepared to extract changes in stimulus information. For example, Sokolov's...work with habituation suggests that elaborate neural models of stimulus input can be generated, allowing the input to be monitored without attention as long as the stimulus does not change. Almost any change in the stimulus will cause an orienting response (or require attention). The neural model achieves its efficiency by performing routine memory checks without attention, presumably freeing the more executive functions for other higher-order processing. Thus, perceptual processes can be automated with an effect similar to that arising from automation of motor processes. The automation to which we refer here extends the range of perceptual automation into the realm of visual search and leaves open the possibility that a model similar to Sokolov's could be extended to handle a wide variety of perceptual skills requiring the rapid monitoring of routine input. Our present findings are of interest over and above the earlier finding that attention can be directed on the basis of conceptual categories. They imply that although subjects can ignore well learned characters, they cannot ignore characters because of an absence of substantial memory representations. The finding that automated accounting for stimuli requires well developed memory representations seems most concordant with the nature of skilled perceptual performance.

2.5 Further Implications of the Search Model

The effect found by Reicher and his colleagues is quite strong. They believe that it has widespread practical applications in the area of pattern recognition and reconnaissance. The general principle seems to be one that pervades all human perceptual and motor performance. Skilled performance depends upon developing highly practiced schema that can monitor both perceptual and motor activities at levels below conscious awareness. Such automation of relatively routine aspects of perception and performance frees the limited capacity of the conscious or central processor to cope with nonroutine or unexpected intrusions into the ongoing routines. The big problem facing the novice or nonexpert in any field is knowing what he can ignore so that he can focus upon what is relevant. Part of this problem is having the necessary conceptual apparatus to segregate irrelevant from relevant.

As just one example of the generality of the principle that one can segregate out and ignore only that for which one has well-developed schemata, we can point to research done with quite different stimulus materials and within a completely different theoretical objective. Geiselman (1975) was interested in testing out hypotheses about cued forgetting with prose materials rather than unordered lists of words. Geiselman interweaved two prose passages, each with a different

theme. His subjects read this intermixed material under instructions to remember only the material relevant to one of the themes and to forget the other material. Sometimes the sentences of the passage to be forgotten were scrambled, sometimes the sentences of the passage to be remembered were scrambled, and sometimes both passages were scrambled. When the target sentences were ordered rather than scrambled, this helped recall somewhat (an increment of approximately 1/10 of an additional sentence recalled out of a total of 10 sentences), but having the background sentences ordered rather than scrambled helped recall twice as much. As in the Reicher experiments, having a coherent background appears to be much more important in being able to ignore the background than having a coherent target. Among other interesting things, Geiselman's data also demonstrate a cost-benefit outcome--the gain in recall for items that subjects are supposed to remember is exactly cancelled out by the loss in recall of items they are supposed to forget.

2.6 The Generation of Visual and Verbal Codes

Rogers completed her doctoral dissertation under our sponsorship. She hypothesized a symmetry between generating and using visual codes and generating and using name codes. Her results indicate, contrary to earlier models of information processing, that subjects tend to generate both visual and verbal codes (rather than just one or the other) to handle identification and sentence comprehension tasks.

3.0 CATEGORIZATION

The level of processing discussed in the preceding section yields as outputs units or chunks that presumably are matched to memory or storage templates to retrieve information to identify the syntactic or semantic possibilities for that component. In other words, such units serve as the basis for a lexical lookup. The results of this lookup provide the basis for identifying the underlying concept, classifying it, or otherwise employing it for propositional representation and eventually providing a semantic interpretation. Although standard pattern recognition tasks, which require simply that a given pattern be classified into one of a specified set of categories, are not lexical lookup tasks in the strict sense of the term, they bear enough resemblances to a lexical lookup and categorization task to provide useful insights. Some current models of pattern recognition postulate that subjects develop a prototype or surrogate representation for all of the patterns of a given class. A new pattern is classified as a member of that class if it is sufficiently similar to the prototype. Prototype and distance models have now become fashionable also in studies of the subjective lexicon and how categorization of concepts takes place.

3.1 Hyman and Frost on Pattern Recognition

Hyman and Frost presented their paper "Gradients and Schema in Pattern Recognition" to the Fifth Conference on Attention and Performance in Sweden during July of 1973. The published paper (1975) summarizes a series of studies on pattern recognition that was begun during the earlier ARPA contract. The final data analyses and preparation of the paper were supported by the current contract.

The work on pattern recognition involved learning to classify dot patterns into appropriate categories. As such, it does not directly deal with semantic memory or instructional technology. Yet the work is highly relevant for a number of reasons. One compelling reason is that models of pattern rec gnition appear to be formally closer to models of comprehension than do other models of cognitive processes such as those employed to deal with human problem solving and decision making. From the outset, models of pattern recognition have involved networks with nodes and connecting lines indicating relationships. Also, these models have more often focussed on branching, parallel processes rather than sequential stepwise processes. Semantic network models, in all these respects, have a very close affinity to pattern recognition models.

An important issue in the study of pattern recognition is how to include within the same framework processes that involve distance concepts measured in a continuous medium with processes that involve discrete categorization of items into mutually exclusive and possibly discontinuous classes. A related question involves the distinction among template, feature and distance models. All these distinctions find parallels in attempts to deal with semantic networks and operations upon them.

Hyman and Frost compared three models of pattern recognition. An exemplar model assumes that the subject stores representations of each instance of a concept that he encounters. When he encounters a new object he compares it with the internal representations he has stored for various concepts. If the object is sufficiently similar to one or more stored representations of a given concept, he "recognizes" it as an instance of that concept. As our own work demonstrates, this model has a range of situations over which it is valid. Its main weakness for serving as a general model of how to recognize and classify new patterns or words or objects is the tremendous load it places upon memory and memory search processes.

Since Bartlett's (1932) classic work on memory, various versions of a schema model have been proposed to explain how individuals can deal with new patterns and information in an efficient manner (Attneave, 1957; Posner & Keele, 1968). The schema model assumes that the subject creates a single, composite representation to replace the individual representations of the separate exemplars for each category. When the subject encounters a new object he need only compare it with the single stored schema for each concept to decide which, if any, of his stored concepts the new item belongs to. Posner and Keele, for their situations, found evidence to support this model. Their results have been confirmed by others. Hyman and Frost found that this model indeed best describes the classification behavior of subjects for at least one type of pattern.

This schema model, borrowed directly from research on pattern recognition, has become quite popular in recent studies of semantic memory.

Hyman and Frost's third model was the Rule Model. This model assumes that the subject abstracts from the exemplars of the different classes those common dimensions or attributes on which the members of the different classes can be discriminated. This assumes, of course, that subjects can find such dimensions which can be used to discriminate members of one category from another. Again, Hyman and Frost found that this model too had its range of validity. The three

different models are by no means mutually exclusive nor exhaustive: the lesson these findings hold for pattern recognition probably holds (if anything, more so) for semantic memory. The issue will be not to find which model of classification and comprehension best fits all situations, but under which conditions can we expect to find one model operating as opposed to the others?

3.2 A Quasi-Semantic System

Corbett applied the speed-accuracy paradigm to test different models of how individuals learn to classify objects in a quasi-semantic system. His subjects learned a set of patterns that varied in whether they were crosses or Ts and in terms of the length of the horizontal and vertical components. They learned both a major and minor category in which each pattern belonged (hierarchical system), labels for the individual items as well as subordinate and superordinate categories. The subjects were tested both on visual and verbal aspects of the system. In the perceptual task, the subjects classified the pattern as if they were employing a weighted prototype of the visual features. This tends to support pattern recognition work of Hyman and Frost, Posner and Keele, and others. But the verbal task suggested that they did not carry over this strategy to the figure names. It could be that the speed-accuracy task encouraged two different strategies depending upon the form of the stimulus material.

4.0 PROPOSITIONAL REPRESENTATION

The basic unit of storage in long term memory is the proposition. At least this is the position taken by most theorists in the area of semantic memory. According to this viewpoint, individual concepts as such, for example the concept of "dog", or of a particular dog such as "Fido", cannot be stored in isolation. Rather, the basic unit consists of a concept and a relation. Sometimes the "relation" is nothing more than a property or categorization asserted about the concept. For example, "Fido is brown", consists of the "relation" "IS BROWN" and the concept "FIDO". Such assignment of properties or categories to concepts can be looked upon as part of lexical memory. Sometimes the relation enjoins or connects two concepts. "FIDO IS JOHN'S DOG" can be broken down into the relation "POSSESS" and the two concepts "JOHN and "FIDO". Presumably such statements of relationships, especially those of family, also form part of semantic memory. Other propositions connect two concepts by a relation of action. "Fido bit Bill" involves the relation "BITE" and the concepts "FIDO" and "BILL". This last proposition could be part of an episodic memory for a particular happening that occurred in space and time. Our lexical memory, which includes general knowledge about Fido and Bill, helps to give meaning to this episode.

The three most ambitious attempts to specify a complete system of representation for semantic memory are the HAM system of Anderson and Bower, the ELINOR system of Lindsay, Norman and Rumelhart, and the system developed by Kintsch. We might also add the conceptual dependency system of Roger Schank. Kintsch takes the position that his propositional notation only covers linguistic aspects of memory. He explicitly allows for nonpropositional information (such as images) to be in memory and play a major role. The developers of HAM and of ELINOR disagree. They assume that all memory, be it verbal or nonverbal, is

propositional in nature. What they want to emphasize is that even "picture-like" memory is really highly analyzed and stored in the form of relations among items. The issue is left open as to whether the sort of propositional network underlying "imagery" might differ qualitatively or quantitatively (more densely connected, say) from that underlying verbal knowledge. At this point it is more a matter of metaphysical preference rather than one of empirical evidence.

Systems of representation at the propositional level differ in more fundamental ways from one another. Wickelgren (1975), as a contribution to this project, published a theoretical and conceptual analysis of these different modes of treating propositions.

4.1 Wickelgren's Analysis of Propositional Repres..ations

A proposition can be viewed as consisting of a "subject" (S) and something predicated about that subject. The predicate often can be subdivided into an action or relation ("verb", V) and an "object" (O). Many propositions, then, can be looked upon as containing the three elements S, V, O. Anderson and Bower employ what Wickelgren calls a "predictable grammar" for their basic memory unit. In a predicate syntax the subject is isolated from the predicate. The basic grouping is (S), (VO). Anderson and Bower assume that such a grouping should be reflected in memory. For example, they would predict that using the object as a probe should facilitate recall of the verb more than it should facilitate recall of the subject. Kintsch and Norman and Rumelhart both employ variants of what Wickelgren calls a "relational syntax". Schank also employs this type of propositional representation. As the name implies, the relation is the key item around which the proposition is organized. Indeed, the relation is a sort of schema which carries slots for different sorts of cases that it demands. For example, the relation "GIVE" comes with slots to be filled for an AGENT (the giver), the OBJECT (what is given), and the RECIPIENT (the person who gets the object). Here the grouping in memory might be viewed as (V), (SO). Presumably, using the object as a memory probe should facilitate recall of the subject rather than of the relation.

Wickelgren isolates a third type of syntax which is currently not employed in any of the theoretical systems. He calls this an "operator syntax" because it represents situations in which a subject is operated upon tc produce a new result (e.g. an image is rotated by 45 degrees). In this sort of grammar, the subject and the action make a grouping and the situation would be represented as (SV), (O) [read "Apply operation V to S and produce result O]. Wickelgren speculates that the operator syntax might be more characteristic of what we call nonpropositional knowledge (imagery, motor programs). Even more speculative is Wickelgren's suggestion that operational syntax might characterize right hemisphere thinking while predicate syntax might characterize left hemisphere thinking. Wickelgren, on logical and intuitive grounds, does not believe that relational syntax is a plausible form of representation for human memory.

4.2 Dosher's Master's Thesis

Wickelgren's student, Dosher, completed her master's thesis on propositional memory. She employed the speed-accuracy tradeoff function (see below) to tease out component processes in retrieving information from semantic memory. She

tested three different models about how information contained in propositions is represented in memory. All the current models assume that items of information (concepts) can be represented as nodes of a network and that the connections or relations between concepts can be represented as labelled links. Dosher used a basic sentence form that involved a subject, an object, a verb, a location and a time (S, V, O, L, T). An example that Anderson and Bower made famous (or infamous) in their book "Human Associative Memory" is: "The hippie kissed the debutante in the park yesterday." Dosher wanted to test for predictable consequences implied by different theories of how such propositions are represented in memory.

She had her subjects learn sets of sentences that consisted of subject, verb, object, location and time. Subjects were then tested with various combinations of such constituents (say S and V) as cues to see how well they enabled them to retrieve the rest of the sentence.

Dosher's speed-accuracy functions revealed that context was in ed treated separately from the subject-verb-object combination. But the subject-verb-object combination behaved as a unit in retrieval, contrary to the model of Anderson and Bower. Dosher also concluded that her data were consistent with a continuous buildup of information about the sentence during retrieval.

4.3 Recognition Memory for Sentences

Begg and Wickelgren (1974) published a study on recognition memory for sentences. The results indicate that the forms of the retention function for entire sentences is the same as the form for other types of verbal memory such as word pairs, words, etc. To the extent that this finding is general it suggests that what we have learned about memory for nonsense syllables and isolated words may have some applicability to more complex and meaningful materials.

5.0 SCHEMATA AND HIGHER ORDER STRUCTURES

5.1 Loading Constructed Data Bases

The first experiment in our series served a number of objectives. We wanted to see how feasible it was to "load" a constructed data base into a subject's memory and then test the consequences. The data base consisted of simple propositions, embedded in a quasi-narrative, about hypothetical individuals. Each individual was characterized by at least three propositions. One proposition told where in the hypothetical city of Plainview he lived. Another told which subculture he belonged to. And the third informed the reader whether he was for or against the construction of a proposed civic center.

The attribute of geography had four locations (NE, NW, SE, SW); the attribute of subculture had four values (college, business, retired, military); and the attribute of issue had two values (for, against). This created the possibility of 4 x 4 x 2 = 32 combinations or "roles" into which we could assign individuals. We deliberately created "structure" or redundancy in our data base, however, by usning only 16 of the possible 32 roles. We did this by creating a dependence between subculture and issue. All members of the college and business subcultures were for the civic center, and all members of the retired and military subcultures

were against the civic center. This reduced from eight to four the number of combinations of values on the attributes of subculture and issue. We kept the attribute of geography orthogonal or independent of the other two attributes--all 16 combinations of the four geographical locations with the combined four subculture-issue combinations occurred.

With this built-in structure we hopefully created a situation in which each item or individual in our data base would be stored as a member of two independent structures. One structure was the geographical quadrant of the city. The other was the hierarchical structure created by issue and subculture (the subcultures being "nested" within the values on issue). We hoped this might provide a start towards studying the issue of multiple versus single memory locations for the same item. Koler's research on bilingual subjects (1968) provides an example of the issue we were interested in. He found evidence that some words, regardless of whether they occurred in French or English, seemed to activate or retrieve meanings from a single, common memory. Other words, however, apparently retrieved meaning only from a separate memory for English or for French.

Another purpose was to see to what extent the subject could retrieve information about an individual's value on a designated attribute without having to retrieve or "look up" the information about the individual's values on the other two attributes. This issue of whether selective retrieval of information is preceded by a prior stage in which all the meanings of a word are activated was examined by Conrad in work supported by our preceding contract (1972b). Conrad concluded that even when the preceding context was clearly unambiguous as to which meaning of an ambiguous word was intended, the other meaning of the word was also activated by its occurrence. For example, in the sentence, "The sailors sailed into the port", the alternative for "port" meaning "wine" was shown to have been activated prior to a selection stage in which the intended meaning of harbor was determined by the context. This finding led Conrad to conclude that even when the context is unambiguous, there exists an automatic look-up stage during which all the meanings of a word are activated.

Procedure. The data base was created to include 16 of the possible 32 "roles" as described above. We assigned 28 hypothetical individuals to the 16 roles. Six of the roles were represented by one individual, eight by two individuals, and two by three individuals. Two things were done to add realism to the data base. The names employed were drawn from the local telephone directory and a narrative was written around the 28 names in which additional details were added. Some individuals, for example, in addition to being identified by occupation, geography and issue were described as meeting together for a weekly poker game. Two individuals were engaged to be married. Some of the individuals were active in the campaign to influence the vote on the civic center. Undoubtedly, these additional embellishments made some individuals more salient than others; they also created stronger ties between some individuals than between others.

Three of the experimenters served as subjects in a preliminary version of the experiment. Four paid subjects provided the main body of data. Each subject was instructed to study the narrative and learn as much as he could about the individuals in the narrative before coming to the first testing session. The

subjects were tested on their mastery by a written examination in which they were given the 28 names and had to supply the appropriate value on each of the three attributes for each name. If the subject could not accomplish this on the first test, he was sent away with instructions not to return until he had mastered the material. Only one of our four subjects seemed to have difficulty in mastering the material. This apparently was a motivational problem, because he achieved a perfect score the next day after being informed that we would have to eliminate him from the experiment. After mastering the material in the data base, each subject then appeared in five different experimental sessions.

During the first session, pairs of names appeared on the cathode ray scope, and the subject had to respond by pushing a right hand key if the two names were the "same" on their geographical value; otherwise he pushed the "different" key. During the second day, the subject had to decide whether the two names were "same" or "different" on their value of issue. The third session was again devoted to issue and the fourth was on geography. For completeness, we ran a fifth session in which the target attribute was subculture. Only one attribute was relevant during any one session. The sessions lasted approximately an hour each.

Because we wanted to achieve enough replications of each pair of names to obtain stable data for each subject, we used only 48 pairs of names out of the total set of 378 possible pairings.

Results. The dependent variable was reaction time for recognizing a given pair as "same" or "different" on the relevant attribute. Our independent variable was the number of shared properties the two names had on the irrelevant attributes. When the target attribute was geography, the number of shared properties on the irrelevant attributes of occupation and issue made a consistent difference both on the "same" and the "different" matches. When two names were the same on occupation and issue as geography, the time to react "same" was 1.34 seconds. But when the two names differed on both occupation and issue, the time to respond that they were same on geography rose to 1.83 seconds. When the two names differed on both issue and occupation as well as geography, the time to respond "different" was 1.94 seconds. But when the two names were the same on occupation and issue, the time to respond that they differed on geography rose to 2.41 seconds. These findings when geography was the relevant dimension are consistent with the idea that the subject automatically retrieves all the information about each name in making his judgment about a single attribute.

The results when issue was the relevant attribute present a different story. When two names differed on both geography and occupation, the time to recognize them the same on issue was only .06 seconds slower than when they were the same on all attributes. Because of the interdependence of issue and subculture, two names that differ on issue had to always be different on subculture. However, reaction time to recognize a pair as different on issue was only .08 seconds when they were the same on geography. These results when the target attribute is issue suggest very little effect of the irrelevant dimensions.

Discussion. These findings are susceptible to alternative interpretations. Issue was a dichotomous attribute; whereas geography had four values. It could

very well be that the presentation of a name starts an automatic lookup process that retrieves the values on each of the attributes in parallel. But it may take longer to retrieve the value for a four-valued attribute than for a two-valued attribute. This differential could explain the asymmetry of our findings. Another possibility is that the subjects organized the names in their memory primarily in terms of the dichotomous attribute of issue. When given a name they first retrieve the value for issue. If the task demands only this information, the search can stop at this point. If the task demands information about geography, however, they have to get to geography by first retrieving the value on issue.

In addition to ambiguous interpretations of our results, our initial study suffers from a variety of other confoundings. We used only 48 pairings of the 378 possibilities. With many repetitions over several sessions of the same 48 pairs, it is possible that subjects could have learned specific information about these particular pairs. For example, some pairs were always "same" no matter what the target attribute. The fact that some names were related by textual relationships extraneous to the three attributes employed in our testing also created systematic, but unwanted, variations in response times. For example, the pair of individuals who happened to be engaged in the narrative were responded to as "same" much faster than other pairs that shared all three properties in common.

By employing a variety of supplementary analyses we convinced ourselves that the results could not be explained away by many of the obvious artifacts that might have arisen because of the various confoundings. Nevertheless, we felt we had tried to accomplish too many goals with one study. The next study was undertaken, consequently, to reduce the number of variables and to unconfound some of the possible findings.

Overall, however, this first study was quite encouraging. It convinced us that we could successfully load a narrative-like data base into subjects' memories and, despite great individual differences in strategies employed to master this material, we could obtain highly systematic and meaningful data in later tests based upon this implanted data base.

5.2 Hyman, Polf and Wedell: Experiment II

In this second experiment we made a number of changes to unconfound and control more sources of variation than in the preceding study. We used four attributes to describe our individuals, but this time all attributes were dichotomous. We also eliminated the redundancy that we used to create structure in the preceding experiment. This time all the attributes were orthogonal in the sense that every one of the $2 \times 2 \times 2 \times 2 = 16$ possible roles was represented. Rather than allow the saliency of the individuals be a haphazard affair, we attempted to deliberately manipulate the saliency of individuals. Within each role we had two names; for one name in each role we deliberately added more descriptive information. This was an attempt to make one name salient and one less salient in each role category. As before, the basic propositions for each name were embedded in a quasi-narrative about the hypothetical town of Oijon through which a river flows. Each individual was characterized by which bank of the river he lived on (East or West); whether he worked as a Planter or Plasterer; whether his recreational hobby was Jogging or Shuffleboard; and what type of bridge he

wanted to see built across the river (Wood or Stone). An attempt was made to use realistic, but not peculiar names. And no explicit connection between individuals was included as part of the narrative. We included a total of 36 names, four names were added to the 32 names that resulted from having one salient and one non-salient name in each of the 16 roles. The four names were added in order to create some pairs of names that were from the same role category and that were both salient or both nonsalient.

Procedure. Four paid subjects first mastered the narrative and then participated in eight testing sessions plus an additional session two weeks after the final session. Each subject was allowed to study the material any way he wished and then he came in for an assessment of how well he knew the material. The assessment session presented the subject with two of the three components of a basic proposition and he had to fill in the third component. For example, he was given a name, geography and he had to respond with East or West for that probe. It took several sessions for subjects to master this material.

After reaching criterion, the subjects were tested in sessions similar to those of the preceding experiment. Each attribute served as the relevant dimension for comparing the name pairs in two different sessions. The total of eight testing sessions, counterbalanced, were administered in a different order for each subject. After an interval of two weeks the subjects were brought back for one additional session to see how fast they retrieved the value of a given name on a specified attribute.

Results. The subjects employed rather elaborate and idiosyncratic strategies for encoding the data structure. Because of the repeated testing necessary before they demonstrated sufficient mastery of the material, each subject quickly realized that all the textual material other than the names and corresponding values on the four attributes was extraneous. Consequently, each subject developed a strategy based only upon these basic propositions. As expected from this strategy, the "salience" of the name as manipulated by us had very meager effects. There was a significant, but very small, effect of the saliency of name pairs during the early testing trials. By the time a subject had participated in half of the sessions, however, every trace of the saliency had dropped out of the response latencies.

Although the encoding strategies described by each subject were elaborate and highly idiosyncratic, they could be divided into two very broad classes. The strategies of three subjects involved coding all the attribute values for a given individual together with the name. The fourth subject, however, learned the attribute values for each name separately for each attribute. She first learned the 18 names that lived on the East bank in alphabetical order. She did not try to learn the list for those on West bank, correctly assuming she could get at these through elimination. After mastering geography in this way, she then learned the 16 names, realphabetized, that belonged to the Planters on the work attribute. Again, she then could identify the remaining 16 by default. She did the same for the remaining two attributes. As we will see, this division of the encoding strategies corresponds to differences in the subjects' abilities to function efficiently in our testing task.

The data for three subjects showed an effect of the irrelevant attributes on time to recognize two names as "same" on the relevant attribute. Unlike the situation in the preceding experiment, however, the time to recognize two names as "different" was not influenced by the number of common properties on the irrelevant dimensions. Hawkins, who was a visiting professor in our department this year, suggested one model that might account for this asymmetry between same and different classifications. Essentially, he suggested that the subject sets up in memory a positive target set of names when he is given the task of matching names on a given attribute. If the relevant attribute is geography, say, then the subject would set up a positive set consisting of those names that, say, live on the East bank. When presented with a pair of names, the subject would search serially through his positive set to find a match. If one name appeared on his list he would continue on through the list until he found the other name. If he found it he would respond "same". If he found only one name on the list, he would respond "different". If he found neither name on the list, he would respond "same". Such a model would easily account for the fact that essentially the different response has the same reaction time for all pairs. And it would account for the effect of irrelevant dimensions on "same" if the names on the positive list were arranged in terms of their similarity on the irrelevant dimensions.

Various other implications of Hawkins' model, however, did not hold up. For example, if the model is correct, the dependence of the "same" response on common irrelevant properties should hold only for one category of the relevant attribute and not for the other. But in our data, the dependence tends to show up f[illegible] categories.

Reed, a former graduate student, has suggested another search model that is better in accord with the data. He suggested that the subject has set up in his memory a single list of the 36 names. Regardless of which dimension is relevant, he searches through this list serially, in the same order. Say the task is to decide if Norman Osbourne and Arthur Backman work at the same occupation. The subject's search strategy is to scan the list for a perfect match to his probe. His first probe consists of "Norman Osbourne works as _____", and "Arthur Backman works as _____". He scans the list until he comes to a proposition whose first two terms match either of these probes. Say he first comes upon "Norman Osbourne works as a Planter." He now inserts "Planter" in his probe for Arthur Backman. He continues through his list until he finds a match to "Arthur Backman works as a Planter". If he does he stops and responds "same". If he does not find an exact match he continues through the entire list and then responds "different". Such a model easily accounts for why all the "different" responses are generally slower than the "same" responses and do not vary as a function of irrelevant properties. If the names on the list are arranged according to similarity between adjacent pairs on shared properties, the model would also account for a tendency of "same" responses to be faster for those pairs that share common properties. Because it is impossible on a linear arrangement of names to be consistent in keeping names with shared properties together, there are further implications of the model. With some additional plausible assumptions, the model predicts that the effect of the irrelevant properties on the "same" responses will be very strong for one attribute and progressively weaker for the others. Our first check on this seems to suggest that this is so.

We have still not done all the analyses to see if this latest model or some other model can account for all our data. Finding an appropriate model to account for these data, of course, is of considerable interest. But our major concern is with another implication in the data. As indicated, only three of the four subjects showed this tendency for the "same" responses to depend upon the irrelevant attributes. It was just these three subjects who encoded their data bases in a way that grouped all the properties together with a given name. The fourth subject, whose "same" judgments were independent of the irrelevant attributes, was the only one who encoded the information about names independently for each attribute. In other words she filed names by attribute values rather than file attribute values under names.

We conducted an extra experimental session with all four subjects to see if retrieval of information about properties on one attribute was independent of retrieval of information about properties on other attributes for a given name. For the first three subject, as expected, there was a strong and significant correlation between the speed of retrieval of information for a given name on one attribute with the speed of retrieval on another attribute. For our remaining subject, there was no correlation whatsoever. These findings emphasize again that the former subjects have stored information about a given individual in one place while the latter subject has not. Another finding of possible significance, although we must be cautious because the data are from only one subject, was that this latter subject showed by far the most forgetting when brought back two weeks later. It could be that storing all the properties together for a given name creates a memory structure that is much less susceptible to later memory loss.

Our third experiment was oriented towards those implications having to do with the effects of the initial encoding. Our intention was to see if we could manipulate the encoding strategy that subjects employed in learning our material.

5.3 Hyman, Polf and Wedell: Experiment II

In this experiment we no longer allowed the subject to master the material in his own way, nor did we embed the material to be learned in the form of a running narrative. The subject was told that he was to learn a list of names and three "facts" about each name. One fact indicated where the individual lived (East or West); a second fact indicated his occupation (Farmer or Grocer); and the third fact indicated how he would vote on the type of bridge construction (Wood or Stone). Some context for these facts was supplied. With three dichotomous attributes, each orthogonal to the other, we had eight different roles or combinations of values. To each role we assigned four names. We thus had a total of 32 different names or individuals; with three facts or attribute-values for each name, there was a total of 96 separate propositions that each subject had to learn. The names were realistic, but with the restriction that each was exactly 13 letters in length. Some examples are Clarence Adams, Terry Albright, Arthur Backman and Robert Caywood.

The first part of the experiment consisted of the subject learning, in a paired association format, to provide the appropriate attribute value when presented with a name and the attribute. For example, if he were shown "Clarence Adams lives _____" on the cathode ray tube, he would have to supply the value

"East" or "West" depending upon which was correct. A given subject always went through these 92 propositions in a given order until he reached our criterion of almost perfect performance. This typically required as many as four or more sessions of one hour each.

To encourage different encoding of the material, the order of the 92 statements varied among our four experimental conditions. In Conditions 1 and 2 we blocked the statements by name. The three propositions about Clarence Adams (lives, works, votes) would appear in sequence, then the three about Terry Albright, etc. In Condition 1, the sequence of attributes was the same for each name. In Condition 2, the sequence varied for each name. We hoped that this form of presentation would force or encourage the form of encoding by name that we observed in the majority of the subjects in the preceding experiment. In Condition 4, we blocked the statements by attribute. All of the statements about where individuals live occurred first, then all of the statements about occupation, and finally all of the statements about voting. We hoped that this format would encourage an encoding in terms of attributes rather than names. Condition 3 was a control in which the 96 statements were mixed randomly with no ordering either in terms of attribute or name.

Following mastery of this material, subjects were tested over three sessions on just one attribute with pairs of names. When presented with a pair of names, the subject had to respond "same" or "different" in terms of that attribute. Care was taken to use a different set of pairs with the value of "same" or "different". The reason for testing on only one attribute was to eliminate the possibility of response competition as an explanation of our effects. To check on the possibility of such response competition, we added a final session in which the subject had to switch to a second dimension for the matching procedure.

Because the PDP-15 was behaving erratically during the conduct of our experiment, we will not present our results. On several occasions the computer broke down in the middle of an experimental session. This resulted in a loss of the data for that session. We had to call the subject back on another day and rerun the entire session from the beginning. We do not know in what ways these interruptions and rerunning of our subjects may have distorted our results.

One thing we quickly learned, however, is that the difficulty of learning the paired associates to the same 96 items varies enormously depending upon the ordering of the items. This suggests that the subjects are learning more than just which attribute value goes with which name-attribute pair. Hopefully, it means that they are embedding the entire set of propositions in different structures. Another finding, if we can believe the elaborate, qualitative protocols we obtained from each subject, is that the particular arrangement of names did not prevent each subject from developing and applying rather rich and idiosyncratic learning strategies similar to those employed in our previous experiments when subjects were deliberately allowed to study the material in their own way.

5.4 Nominal and Relative Data Bases

In retrospect, some of our problems with the initial experiments stemmed from the lack of sophisticated descriptive tools. Our data base, while fairly complex with respect to typical learning experiments, were still semantically very primitive. Our entire data base could be viewed as a set of nominal propositions. That is, each molecule of information consisted of an object (a name) and the attribution of a property. We call such a system "nominal" (after Frederiksen) because it serves to identify each object in terms of a classification or attribution without directly linking any object in the system with another object. Whatever organization is created in such a system depends upon objects having shared properties. Such linkages are indirect, occurring through the possession of common elements.

As contrasted with nominal propositions, relative propositions specify a direct relation between two objects. If we say that X is the father of Y, for example, we have a relative proposition that specifies a linkage of a particular sort between the objects X and Y. For the sorts of questions that we were trying to answer in our original experiments, we felt we would gain much more power by employing both nominal and relative propositions within the same experiment. Accordingly we have devised a set of new paradigms that are somewhat more sophisticated versions of the earlier paradigm.

The new experiments differ from the earlier ones in a number of crucial ways. In one sense, they are much less complex. We employ fewer objects in the data base and fewer attributes. On the other hand, we load the data base into a subject's memory in two stages. We first create, for example, a data base from nominal propositions (a lexicon). Once the subject has mastered the first data base, we then teach him a new set of propositions involving the same objects. The new set of propositions are relative, specifying direct relationships between pairs of objects in the initial data base (the relational system).

The experimental task consists of having the subject verify as "true" or "false" new propositions involving the objects in the data base. The new propositions are all relative, specifying relations between the objects in the lexicon which may be true or false. The subject can verify a proposition by using only the information from the relational system. What we are interested in is the extent to which he also uses information from the initial data base to verify the statements.

5.5 Family Relationships

In one paradigm, the subject first learns, for each of a set of names, the sex and age (male or female; age 30 or 5). The names are all neutral in gender so that they do not serve as a cue (e.g. "Chris", "Pat", "Dana", etc.). Once he learns the nominal data base of sex and age, he then learns new information about the individuals in the data base--namely who is related to whom and in what way. For example, he may be told that Chris and Kim are the parents of Pat and Dana. He is told a similar relationship system for the other four names in the data base. This information, along with the subject's knowledge of kinship systems and his mastery of the original data base should be sufficient for the subject to answer such questions as: "Pat is the husband of _____?"; "Pat is the father of _____ and _____?"; "Dana is the daughter of _____ and _____?". To be sure, the subject is tested on all possible pairwise relationships between members within a family.

The experimental test consists of giving the subject statements such as "Chris is the father of Jan". He has to respond as rapidly as possible with "True" or "False". We look for the differences in saying "False" to statements in which the two individuals share zero, one, or both properties of age and sex. If the subjects are using the information "associatively" (on one model, for example) we would expect the reaction time to say "different" to be slowest when the two names (the subject and object) share two properties (they would be stored together in the lexicon). On the other hand, if the subject is using the information "semantically", we would expect the subject to be slower in saying "different" when the two names are different in age (because this is semantically possible, but semantically impossible when the two names are the same age).

5.6 Friendship Relationships

The relation of friendship differs from kinship relation in several ways. It can be reciprocal; it does not order the names in any systematic manner; etc. In a second set of experiments we employed this relation instead of kinship. The nominal data base consists of names and two properties associated with each name--height and geographical origin. Once this nominal system is mastered, the subject then learns which subsets of individuals are friends to one another. In these experiments we always use the friendship relation as symmetrical. If X is a friend of Y, then Y is a friend of X.

With these alterations, the experiments are otherwise parallel in all details.

5.7 Some Tentative Findings

When the relational system is learned at a separate time from the nominal system, for example, we find that, on the average, verification latencies to relational propositions are not influenced in any systematic manner by the information in the nominal data base. This ability to compartmentalize the two systems could be due to their having been learned at separate times or because the two sorts of systems generate organizational structures that can be kept separate from one another.

On the other hand, we find that subjects cannot react selectively to comparisons based on one of the nominal attributes without being affected by information from the other nominal attribute. This effect, however, is different from what we would have predicted from the sort of associational model we found compatible with the earlier experiments. If the subject, for example, has to decide if a pair of individuals is the same or different on height, the decision is facilitated--regardless of whether it is positive or negative--when the two names are the same in geographical origin. This finding is symmetrical. Subjects make faster comparisons on geography if the two names are the same in height.

The finding is compatible with a model that says that the first name of a given pair serves as an entry point into the memory structure. The subject then starts to look for information about the second name at the same address. If the other name happens to be stored at the same location (shares other nominal properties) the retrieval and comparison is relatively fast. If not, the response is slowed down.

We are planning to better control the way the subject has the nominal data base organized by teaching directly a spatial organization for the data base. One situation, for example, will involve a data base on which names are arrayed on a two-dimensional geographical grid. Subjects will be taught the data base in terms of this grid. We can then test to see if in fact the underlying memory structure has either or both the topological and metric properties implied by this organization. We then can test the implications of superimposing upon this spatial organization a relational system such as the family or friendship systems.

5.8 Extensions

The data bases discussed in the preceding section are still relatively primitive. Both the nominal and relational systems employed are all stative systems--that is sets of propositions that identify objects in terms of static classifications, attributes and dispositions, and static relationships to each other such as friendship and kinship. Such data bases correspond to part of what is termed "semantic memory" and to "subjective lexicons". Of more interest will be the investigation of how such semantic memories operate in dealing with episodic events and vice versa. For this latter purpose we will have to introduce action systems and locative-temporal systems. That is, we will want to specify or describe episodes involving actions between individuals in the data base that occur in particular places and times.

5.9 The Impression Formation Task

We wanted to devise a general paradigm that would enable us to investigate how what the subject already knows influences his encoding of new input, not that we doubted the fact that such an influence takes place. To the contrary, much research going back to Bartlett's (1932) classic on remembering and continuing with contemporary research such as that by Bransford and Franks and their coworkers leaves no doubt that what is retained is decisively controlled by how it was encoded.

We wanted to go beyond the further demonstrating of something that we all agree upon. We wanted to see if we could control some of the factors that determine the initial encoding and make differential predictions about the outcome.

One approach to this was Hyman's adaptation of the impression formation task. In this task, the subject is given a description of a hypothetical individual and then describes his impression of that individual on a checklist. The social psychologists typically concentrate upon factors that affect the subject's impression. Hyman adapted this task to focus on factors that affect the subject's memory for the initial description of the individual. The interest is not so much in how accurately he can remember, but rather in the nature of the distortions or errors in memory that occur. Such errors can be used to indicate how the subject has organized and encoded the initial material.

The resulting paradigm has many attractive features. It is easy to generate normative data to indicate how typical subjects react to different descriptions and category labels. The impression task itself encourages the subject to form a coherent organization of the given material without having to tell him to

memorize the material. As a further bonus, the impression task provides us with information about the subject's initial impressions or inferences about the stimulus material. We can thus compare subsequent memory not only against the original stimulus but also against the subject's initial description of that stimulus. And, finally the subjects tell us that they enjoy the task and think it is relevant to what they do in everyday affairs--make judgments about people on the basis of partial information.

Hyman reported the first experiment using the paradigm at the Tenth Annual Carnegie-Mellon Conference on Cognition at Vail, Colorado in June, 1974. This was published in the book edited by David Klahr called "Cognition and Instruction" (1975).

The basic experiment. The subject is presented with a short description of a hypothetical individual. The description includes three components: (1) the individual's name (e.g. Robert Caywood); (2) the individual's occupational label (e.g. Accountant); and (3) a short character sketch written around ten adjective traits (such as "withdrawn", "deliberate", etc.). The subject's task is to form a coherent impression of what this individual is like. He then describes his impression by circling those adjectives on a checklist of 91 traits that fit his impression. He performs this task for three different hypothetical individuals.

Of the three descriptions, one of the pairings of occupational label and sketch is chosen to be "appropriate" and the other two pairings are chosen to be "inappropriate". Appropriateness of the matching was decided on the oasis of normative ratings by a separate group of judges. Different groups of subjects get different pairings of the same set of sketches and labels to counterbalance specific effects of a given label and sketch.

Following the impression task, the subject is then told that we are also interested in his memory for the sketches that he read. His memory for these sketches is tested by giving him the list of 91 adjectives. He is given the name and occupational label of one of the descriptions (e.g. Robert Caywood, the Accountant). He then goes through the list of adjectives and indicates which ones he believes were in the original sketch of Caywood. For each adjective he indicates not only his judgment, but also his degree of confidence in that judgment. Essentially, this amounts to a rating of each adjective from "1" (very confident that it was in the sketch) through "6" (very confident that it was not in the sketch).

The purpose of the first experiment using this paradigm was to look at the effects of discrepancy from stereotype upon recognition memory. In the appropriate matching of category to sketch, we would expect a high "hit rate"--that is a strong tendency to rate high those adjectives that were actually in the sketch. At the same time, however, we would expect a strong "false alarm rate"--that is a strong tendency to also rate high adjectives that were not in the sketch but which are consistent with the stereotype that goes with the category label.

When the category label was grossly mismatched to the character sketch, we expected to observe both a low "hit rate" (since the category label no longer helps to suggest which adjectives are relevant) and a low "false alarm rate" to adjectives that are related to the category label (because the subject probably remembers that this individual was not typical of accountants, etc.).

The most interesting case for our predictions was when the label was only mildly inappropriate. Here we hoped that the mismatch would not be too obvious, encouraging the subject, instead, to generate a coherent impression that integrated label with sketch. We expected most memory distortion to occur in this case. Here we expected the impression of the sketch to be assimilated to the category label. Whereas in the case of the grossly inappropriate label, we expected a contrast, rather than an assimilation effect.

The experiment, thus, predicted different sorts of memory for three different degrees of appropriateness. The experiment failed in helping with this prediction because it turned out we had effectively just two levels of appropriateness--an appropriate match and a mildly inappropriate match. Indeed, it is quite difficult to generate a sketch and a label that most of our subjects cannot integrate into some sort of a plausible impression.

As expected, appropriate labels tended to reinforce the tendency to false-alarm to adjectives that fit the stereotype that go with the label. When Robert Caywood, whose sketch is appropriate to the image of an accountant, is labelled as an accountant our subjects tended to falsely remember that he was described as "mathematical", "careful", "consistent", "methodical", "precise", "systematic", and "economical" much more frequently than when the same sketch was labelled as that of a "Social Worker" or "Lawyer".

However, our results make it clear that we cannot simply conclude that memory is distorted to fit the label. We have to qualify such a conclusion in at least two ways. One way is that distortions occur mainly when the label is appropriate. An appropriate label tends to encourage false recognition of adjectives that are consistent with the label. But inappropriate labels, in general, do not encourage false recognition. There is little overall tendency to falsely recognize adjectives that are related to the label when it is inappropriate.

Accuracy of recognition, as determined by the relative ability to discriminate correct adjectives from related foils, is just about equivalent for the appropriate and inappropriate labelling conditions. In the appropriate condition, there are fewer false alarms, but there are also fewer hits.

The preceding conclusions are correct when we average over the three different sketches. But they must be further qualified because of specific interactions between particular sketches and particular labels. One of the sketches, "Robert Caywood", was written to be compatible with the stereotype of "Accountant". The major effect for this sketch occurs when the appropriate label is assigned to it. This enhances strongly the tendency to falsely remember Caywood as having been described as "systematic", etc. At the same time, when assigned the label of "Social Worker" or "Lawyer" no tendency emerged to falsely recognize adjectives relevant to either of these latter two labels.

The sketch "Decker" was written to be compatible with the stereotype of "Lawyer". The major memory distortion that took place with this sketch was when it was assigned to the category "Social Worker". This latter label strongly enhanced the tendency to falsely remember that Decker was described as "charitable", "friendly", etc.

The third sketch, "Fleming", was written to be compatible with the stereotype of "Social Worker". Here we found that the application of the appropriate label reduced the tendency to falsely remember adjectives appropriate to an accountant. In addition, assigning the label "Lawyer" to Fleming increased the tendency to falsely recognize such adjectives as "persuasive", "aggressive", etc.

In short, the label does make a difference in recognition memory. The specific effects of the label, however, varies with the sketch and the label. The sketch for Caywood differs most from the other two sketches on a number of independent and normative measures. For this reason, it is probably most difficult for the subjects to perceive Caywood as a plausible lawyer (he is described as "withdrawn" and "distant") or a plausible social worker (also because of his anti-social traits). As a result it is possible to distort both the impression and memory for Caywood towards the image of a withdrawn, meticulous, compulsive individual by appropriate labels, but it is probably difficult to distort the image of Caywood towards the generous and warm stereotype of the social worker or the extroverted and forceful image of the lawyer. The sketch for Fleming describes his warm and generous social tendencies. Calling him a social worker confirms these tendencies and contrasts them with the cold and niggardly image of the accountant. Labelling Fleming an accountant does not make it easy to assimilate his good-guy picture to the socially negative traits that form the stereotype of an accountant. But there is no incompatibility of being socially positive and being aggressively persuasive, even though these two might not be highly associated. Consequently labelling Fleming as a lawyer makes it easy to attach to his existing image the traits of a lawyer.

Additional findings from the impression task add to these results. Almost all of the effects we find on the recognition test are found in the impressions as indexed by the check list. This finding excludes the possibility that we are dealing with a bias that is induced by the label at the time of recognition testing. Because the impression task occurs immediately after initial exposure to the sketches, the evidence is that the memory effects are due to the initial encoding of the sketches and not to subsequent effects of the label at testing. Further analyses (analysis of covariance and related tests) indicate that the impression is not the cause of the recognition memory, but is itself a dependent variable which is also affected by the initial encoding.

5.10 Subsequent Experiments with the Paradigm

We conducted two additional experiments within this paradigm. Both are identical to the basic experiment with only minor changes. In the second experiment, we inserted a free recall task in between the impression and recognition memory tasks. The results for the recognition data are basically the same as for the first experiment. The recall data show the same pattern as do the recognition data.

The third experiment attempted to emphasize the effect of the label. It did so by first having the subject form his impression to the individual on the basis of the label alone before he was shown the character sketch. Again, the results simply confirm those of the previous two experiments.

5.11 Additional Variations

We tried a number of variations on the basic paradigm. One reason is that our initial sketches were internally consistent. Against such a homogeneous set of ten descriptors, the category label--especially when inappropriate--was relatively impotent. The label effects, while highly consistent and significant, were quite small relative to the huge effects due to the overall sketch (we also had normative data on the impressions generated by the sketches in isolation from the labels). A more fruitful approach, we reasoned, was to create inconsistency within the sketch itself.

We created a new paradigm to do just this. One of the experiments we completed was done as follows. The subject is given a coherent and homogeneous character sketch of a hypothetical individual. As in the previous experiments, the subject forms an impression and describes it by means of a check list. Then we supplied the subject with additional information about the given individual. The new information is also in the form of a character sketch. But half of the new information is consistent or "appropriate" to the original information and half is not. We then have the subject form a revised impression of the hypothetical individual. Finally, we have him indicate his memory for all the adjectives used to describe the individual in a recognition test.

The subjects tend to give the same ratings (have the same "hit rates") for both the consistent and inconsistent information in the second sketch. But the false alarm rates for associated foils are quite different. The subjects have high false alarm rates for foils that are consistent with the initial sketch; they have low false alarm rates for adjectives that are related to the inconsistent information.

This indicates that the subjects encode consistent information in a highly generic (top-down) way. If the hypothetical individual was initially described as socially outgoing and warm, they will encode a consistent adjective such as "charitable" as simply confirming the "good-guy" image. In later recognition testing they will not only tend to correctly recognize "charitable", but also "friendly", "helpful", and other adjectives that were not in the sketch but which are consistent with the "good-guy" image. But if the hypothetical individual had initially been described as socially withdrawn and calculating, they will tend to encode the now inconsistent adjectives such as "charitable" in a highly specific (bottom-up) way to make it compatible with what they already have learned. In this second case "charitable" will not be encoded as consistent with a "good-guy" image, but rather something specific might be extracted, such as a man who donates to charities in order to gain an income tax benefit. In this latter case, there will be no tendency to confuse in later recognition the memory of "charitable" with foils such as "friendly", "generous", etc.

5.12 Linear Orderings

O'Dell completed her master's thesis under our sponsorship. Her research was concerned with the memory representation and strategies that subjects employ when they learn a linear ordering of items along a spatial dimension. Potts and Bransford have shown that when a person is asked to learn a set of sentences that describe a linear ordering of items along one dimension he encodes the

relative positions of the items rather than the sentences. In addition, the time required to verify the relative positions of two items along a dimension is a monotonically decreasing function of the distance between the items.

Propositional encoding theories and verbal associative models both would predict that the closer two items are along a dimension the faster one could verify their relative positions. But, instead, the results are better predicted by a model (Moyer) in which subjects represent the items along an imaginary spatial dimension and make position judgments similar to psychophysical judgments. If this model is correct, practice should have little effect on the shape of the function while lowering the overall time required to make the judgment. Also, different linguistic surface structures of the sentences presented while learning should result in identical representations. This also, according to O'Oell, should argue against a linguistic encoding strategy.

O'Oell's findings were completely in accord with the spatial representation.

5.13 Relational Knowledge

Farley, under our sponsorship, also began a series of investigations that were inspired by work on the representation of linear orderings. Farley was interested in the implicit or inferential information one attains when he has learned a knowledge structure. For example, given the linear ordering expressed as: "A is left of B. B is left of C", one can answer that A is leftmost or that C is right of A.

Farley discusses three classes of theoretical models to account for such knowledge acquisition. The Storage and Inference model (SI) proposes that the individual propositions, such as a pair-wise relation, are stored separately. Though stored separately, the propositions are organized during acquisition so as to facilitate future inference operations. As far back as 189D, William James described inference in an SI model as the process of expunging intermediary terms. The SI model, although amended and improved by Clark, has many glaring deficiencies. Especially damaging is the finding such as in O'Oell's thesis that time to answer a question requiring inference is inversely related to the number of inference operations required by an SI type of model. Of more concern to Farley, is the model's inability to account for knowledge acquisition in non-linear structures such as family trees.

The Network Construction (NC) and Frame Instantiation (FI) models both propose that, rather than being stored separately in memory, the input propositions, including relational propositions, are combined into a unitary, structural representation. The difference lies principally in their proposals as to the state of memory at the start of the comprehension process. The NC model proposes that memory is a clean slate when comprehension starts (at least with respect to the task at hand). The process of comprehension in this model consists of developing a semantic network which then represents the meaning of the input sentences (HAM and ELINOR would be examples of this model). Only after the input sentences have been represented in a propositional network format is the search for a match in semantic memory made. Knowledge, including inferences, is retrieved from the semantic network by locating a path or paths through the structure from one element to another and noting the relational links which are traversed in the

process. Like the SI model, the NC model cannot account for end anchor effects or the decrease in question answering time with increasing distance in the network.

The FI model proposes that rather than a clean slate, memory initially consists of a contextually determined framework containing unspecified, or "empty", locations. The process of comprehension consists of binding (instantiating) these free locations with meaning elements which are extracted from the input. Comprehension processes are dependent upon characteristics of the contextual frame which is to be instantiated. Generality is achieved by assuming the availability of a large repertoire of frames, the ability to create new frames with experience, and the existence of a general frame to allow some, albeit not as efficient, comprehension in unfamiliar contexts.

Farley elaborates upon various specifications for the FI model. He then illustrates its application to data collected by others on linear orderings. The key feature in his FI model is the idea of primary location(s). The frame consists of a number of locations embedded in a structure of relational links. The frame can be accessed only through its primary location. Once accessed, the frame can be searched only in a sequential fashion beginning with the primary location. For a linear ordering, the primary locations are the ends.

For his experimental test of the FI model, Farley created a linear ordering in which the primary location was not one of the end points. He created a father-son relationship structure of four locations. In this structure, A is the son of B, B is the father of C, and C is the father of D. Farley assumes that the primary location will be B because in this family tree that position holds the position of seniority. He then gave his Ss various surface structure presentations of the names to be inserted into the frame. All told, he used six different orders of presentation. So far, the time to comprehend the input sentences in terms of the family tree seems to be predicted from the FI model assuming that the most senior location is the first position accessed to retrieve the structure. Farley has just begun this line of work and will continue with more elaborate testing of the FI model.

5.14 Motor Programs

Keele (1975, 1976) published two papers, one experimental and the other more theoretical, under our sponsorship on the role of motor programs in controlling sequential movements. Motor programs, surprisingly enough, constitute excellent examples of higher order cognitive structures of a nonpropositional sort. They are central and involve rather sophisticated usage of schemata and templates for controlling the sequence of behaviors which may never be exactly repeated because of different initial conditions and the like.

6.0 OTHER ACCOMPLISHMENTS ANO ACTIVITIES

The preceding report, although long, covered only the highlights of our accomplishments. More emphasis was also given to those studies which have not yet been published. Many other studies, especially some which have been published or are in press, were not reviewed. In part, this was because they did not easily fit into the general framework of the project. Such studies promised to contribute to one or more aspects of our framework when initiated. But, after

completion, reconsideration led me to decide that they do not really directly contribute to the central themes of the project. Yet, many of them are excellent contributions to the experimental literature in their own right.

Another sort of contribution that is not recorded in the main portion of the report is the many developments along methodological lines. Some of these have been described in previous technical reports. After some false starts, problems with our supplier and breakdowns in equipment, we finally installed our new Prime-based computer addition to our automated laboratory. This has extended our experimental capabilities manyfold. Among the important breakthroughs in new methodological tools developed under this contract would be: the speed-accuracy tradeoff paradigm, the impression-formation paradigm, the loading of data bases into subjects, the yes-no recall paradigm.

Wickelgren made many theoretical contributions to the dynamics of memory retrieval. He worked out a single trace theory of memory (to replace the dual trace theory); he worked out the theoretical implications of the speed-accuracy tradeoff function; and he developed a network strength theory that promises to combine the advantages of as associative model with that of a network representation.

7.0 CONCLUSIONS

The list of papers published or to be published as a result of this project gives one measure of our accomplishments. The conclusions and findings outlined in this report gives another measure. But, in my opinion, the best index of how much we accomplished is in terms of seeds we have planted for future growth and development of the framework and research we initiated.

The list of papers and talks is incomplete. Many of our studies have not yet been written up. Some are still being analyzed. Some are incomplete and still in progress.

We can extrapolate to some extent on the impact of our contract. Wickelgren and his students Albert Corbett and Barbara Dosher have obtained a grant to continue the work on semantic memory initiated under the present contract. Both Corbett and Dosher, furthermore, are currently working on their doctoral dissertations, both of which were started under our sponsorship. Reicher and Hawkins have also prepared a proposal for continuing research they began under this project. Reicher developed a paradigm for studying reading in the laboratory during this project. He will now continue his research on reading using this paradigm. Keele has joined with Reicher and Hawkins to study the cognitive aspects of motor skills. They have concluded that skills that require fast adjustments to circumstances (basketball and tennis, for example) can only be accounted for by cognitive models that employ schemata of the type we have been studying in this project. Farley is continuing his studies of the Frame Instantiation model. Tram Neill is continuing studies on level of processing and attention which were started under our sponsorship. And Hyman already has begun to apply the framework and some of our findings to the problem of understanding why people, including scientists, are often badly deceived. The entire field of cognitive error is now ripe for study because most cases seem to be examples of the type of top-down processing we have been considering within our framework.

The theoretical and experimental problem is to be able to better specify the conditions under which preconceptions and top-down processing override inconsistent or contradictory inputs. Probably we will have to bring in motivational factors. It is not clear that such overriding takes place. An alternative explanation is that the deceived person simply avoids getting himself into situations where negative inputs could intrude upon the frame that he strongly wants to instantiate.

8.0 PRESENTATIONS AND PUBLICATIONS SUPPORTED BY ARPA CONTRACT NO. F44620-73-C-0056

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